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Office of Scientific Research and Development

National Defense Research Committee

Section 16.1 - Optical Instruments

Institute of Optics

UNIVERSITY OF ROCHESTER

Report on

DEVELOPMENT OF SPECIAL REFLEX GUN SIGHTS

Contract No. OEMsr-160

September 27, 1945

Section 16.1 Report No. 110

OSRD Report No. 6032

Copy No. 29

Distribution List

of Report on

DEVELOPMENT OF SPECIAL REFLEX GUN SIGHTS

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FOREWORD

Under Project 16.1-5 the development of various types of reflex sights has been carried out at the University of Rochester, for a variety of applications. Use has been made of high efficiency partially reflecting coatings on the dividing plates of some models, particularly when sky illumination of the reticle has been employed.

Under Project NO-103 a radar reflex sight, known as the "Flight Sight" was developed to provide the pilot of a night fighter airplane with a single collimated display which includes, in addition to the usual gunsight reticle, a gyrohorizon, an airspeed meter and a radar screen. Tests of a prototype model in an F4U-2 aircraft at Patuxent River in 1944 showed that the device would probably be extremely useful if the radar display could be increased in brightness. Investigation revealed considerable vibration of the dividing plate which presumably was responsible for reducing the apparent brightness of the radar display. The mounting of the dividing plate was stiffened in August, 1945, but time did not permit testing of the revised model. It seems likely that the radar display will be bright enough for use in moonlight, but it may be necessary to provide shock mounting for the Flight Sight and radar tube.

The following is an extract from a letter written by Dr. J. W. Evans of the University of Rochester on June 28, 1945, describing shake table tests of the Flight Sight:

> "The sight was tested by mounting it as rigidly as possible on our shake table (designed and used for auto-oscillation binoculars). A small point source was set in the focal plane of the objective in the position normally occupied by the screen of the oscilloscope tube. With the shake table running the point source was viewed by (a) reflection from the reflex plate (as it would normally be viewed by the airplane pilot; and (b) by looking vertically down into the objective so that light was transmitted through the reflex plate. Then the laser mirror was removed, the point source was again placed in the focal plane and the above observations were repeated.

"The observations were very definite in indicating that the vibration of the reflex plate is the source of the trouble, while the vibration of the lower mirror appears to have a negligible effect. This means that if the vibration of the shake table is comparable to that of an airplane the definition of the projected image will be vastly improved by mounting the reflex plate more rigidly. There will remain, however, the linear vibration of the sight with respect to the tube (sight mounted solidly on frame of airplane, while the tube is shock mounted). Since the image on the tube is perfectly clear to the unaided eye this linear difference will be simply the linear vibration of the frame of the plane at the point when the sight is mounted. Dr. French thinks it probable that this will not exceed .2 or .5 mm. in amplitude, although only a test with the sight mounted in a plane can decide this point definitely. Such a linear blur would be tolerable."

Section 16.1, NDRC has recommended that the Flight Sight be transferred by OSRD to the Bureau of Ordnance.

Theodore Dunham, Jr.
Chief, Section 16.1, NDRC
Optical Instruments

22-241 Radiation Laboratory
Massachusetts Institute
of Technology
Cambridge 39, Massachusetts
June 10, 1946

Specifications of Objective

No. of SIGHT	LENS	GLASS	INDEX	THICKNESS	DIAMETER	RADII
						166.5
Reflex Sight Objective	1	Pittsburgh Plate	1.523	30.2	95.5	
						-166.5
		Air Space	1.000	5.38		
						-148.6
		DF-2	1.617	9.64	95.5	
						-579.4
Focal length = 305 mm.						
						121.3
S-1	1	Pittsburgh Plate	1.523	22	95.5	
						-121.3
		Air Space	1.000	3.92		
						-108.22
		DF-2	1.617	7.02	95.5	
						-421.99
Focal length = 222 mm.						
S-2 same as S-1						
						166.7
S-3	1	C-1	1.523	7	89	
						∞
		Prism Plastic	1.495		89	
						114.6
Focal length = 135.3						
						72.58
5407	1	BSC-1	1.511	9	42	
						-57.08
40 mm. Anti-aircraft	2	EDF-2	1.689	4	42	
						-152.13
Focal length = 119.8						
						82.8
Maxson	1	BSC-1	1.511	14	64	
						-90.3
	2	DF-3	1.621	2	64	
						∞
						82.8
	3	BSC-1	1.511	14	64	
						-90.3
	4	DF-3	1.621	2	64	
						∞
Focal length = 102.3						

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SUMMARY

The development of several forms of gunsights of the so-called reflex type has been requested of the Institute of Optics and carried through under Contract OEMsr-160. Four main types have been developed, two for airborne use primarily in fighter aircraft, and two for application to the smaller calibre anti-aircraft guns. The first airborne sight to be completed under this project was required to provide an exit pupil aperture of more than 3 inch diameter, to be much more compact than the Navy Mark 8 sight, to give much smaller spherical aberration than this sight, to provide brighter reticle illumination, and to be simpler and cheaper to manufacture. All the requirements were met by a reflex sight in which the optical path between graticle and lens is folded twice by means of plane mirrors, together with a special illuminating system of unusual efficiency. This sight was adopted by the Air Force with modifications in mechanical design to facilitate production and procured under the designation of the M-9. Because of the peculiar folding of the optical path into the form of a figure 4 it is sometimes referred to as the figure 4 sight.

The second airborne sight to be completed was developed to meet specifications of the Navy Bureau of Ordnance and Navy Bureau of Aeronautics for a single optical device which would include illuminated graticle, image of radar cathode ray tube screen, and image of two flight instruments, gyro horizon, and air speed meter, all appearing in the field of view of a pilot looking ahead through the regular reflex gunsight diagonal reflecting plate. This highly special development was required in certain plans for night operation of the F4U2 single seater carrier based Navy fighter plane. Only one sample of this sight was built since change in the Armed Service plans eliminated the requirement for this device.

The first anti-aircraft reflex sight completed under the project was known as the T-67 and was developed for a 40 millimeter gun. Very special requirements were imposed on this development including provision for both electric and daylight illumination of the graticle. Two sights were required per gun to provide for two man tracking, with somewhat different technical requirements for the altitude and azimuth units. The daylight illumination requirement was made difficult by the necessary location of the reflex sights upon the gun. Samples were completed meeting all requirements and passed the tests of the anti-aircraft board very successfully. A special version of the sight provided for radium phosphor illumination of variable intensity to take the place of electric illumination under night and twilight conditions. In this form no electric power supply was required, there being a very satisfactory overlap between the daylight illuminated and radium illuminated graticle permitting operation through twilight conditions. Only slight modifications in mechanical designs were required to meet Ordnance and anti-aircraft production requirements, and very substantial orders were placed for the sights in four modifications known as M-21, M-22, M-23, and M-24.

The second form of anti-aircraft sight was first developed for use on the 50 calibre anti-aircraft gun in ring mount carried by certain 6 x 6 and half-track trucks. This sight was required to be very compact and rugged, to operate entirely with daylight illumination of the graticle, and to be mounted on a parallelogram-like mechanism to keep the sight some 17 inches above the gun barrel to eliminate disturbance of vision caused by muzzle blast. A model of this sight was tested at Fort Knox against airplane towed targets with very good success. Shortly thereafter a request was made for a similar reflex sight to be mounted on the Maxson anti-aircraft turret. It was found that a slight modification of the optical and mechanical structure of the 50 calibre gunsight would meet the Maxson turret requirements. A sample was submitted for test by the Anti-Aircraft Board with very satisfactory performance which resulted in Army Ordnance contracts for procurement of very substantial numbers of this sight.

Details of design and performance characteristics of the above types of reflex sights are discussed in this report.

DEVELOPMENT OF SPECIAL REFLEX GUN SIGHTS

1. Introduction.

Rifles have long been equipped with open sights consisting of a groove or aperture at the breach and a point or bead at the muzzle. The ball and ring sight, with a point at one end centered in a ring at the other allows more head freedom but requires close alignment of the gunner's eye and has the further disadvantage of not allowing simultaneous focus of the sight and the target.

The earliest known use of telescopic sights was during the Revolution, when a simple system was used by the Americans. More developed sights of this type are now in extensive use, with power varying from unit magnification up to 12. They give excellent image quality, with the reticle and target images in the same plane thus requiring no change in focus while aiming, but they have a limited field, are complicated in construction, and have a fixed, narrow eyepoint.

A reflex, or reflector, sight has many advantages over the telescopic type; it allows great freedom of head and eye movement, has a very large field, and is simple to construct. Its primary purpose is to indicate the point of aim of a gun or set of guns by projecting the image of an illuminated reticle accurately in the direction of fire; its secondary purpose is to give some means of quickly estimating the deflections for targets moving across the line of fire. The simple reflex sight in itself gives no magnification. The principal elements of such a sight are shown in Figure 1. An observer at E sees the image of the reticle R apparently at infinity through the transparent plate D. As the eye is moved over an area equal to that of the lens C, the direction of the aiming spot remains fixed, allowing considerable freedom in the position of the head. Because the reticle is independently illuminated by a source at A, it can easily be seen under conditions of poor external visibility.

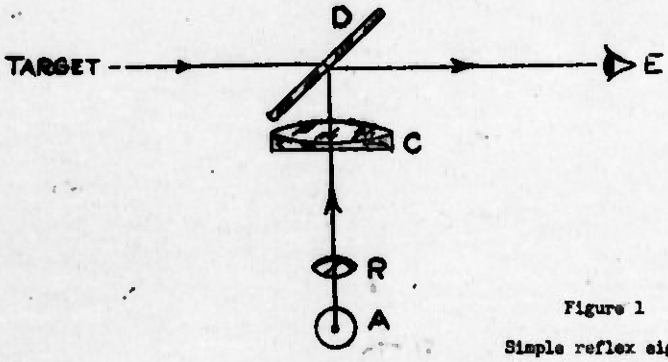


Figure 1
Simple reflex sight

Variations in this design can be made; the sight can be "folded" to make it more compact, the method of reticle illumination changed, and the relative amounts of reflection and transmission of the reflex plate can be controlled so as to give maximum visibility at all times.

Several special types of reflex sights for the armed services have been designed at the Institute of Optics under Section 16.1 of the OSRD (Contract OEMsr-160), at the request of the Navy Bureau of Ordnance, the Army Air Force Materiel Board, and the Anti-Aircraft Artillery Division.

II. <u>Figure 4 Sights</u>. <u>Folded Reflex.</u>

In the early summer of 1942, the Institute of Optics was informed of the shortcomings of the Navy Mark 8 reflex sight, which had been tentatively accepted by the Navy and the Army Air Force for use with aircraft guns.

The Mark 8 had the advantage of being extremely compact, occupying a minimum of volume and obscuring as little as possible of the instrument panel of the plane; it used a short focus, f/0.85 lens of 3-1/2 inch aperture. Objections to this sight were that the projection lens was not sufficiently well corrected for spherical and chromatic aberration, the reticle illumination was so weak that the projected image was not visible against the sky in the neighborhood of the sun, and so uneven that the brightness of the projected image varied considerably as the observer's eye moved across the lens. It was also difficult to produce in quantity because both material and workmanship were critical.

The Institute of Optics was asked to design a sight that would incorporate the compactness of the Mark 8, but would not have the disadvantages mentioned above. To avoid the large aberrations and cost of the f/0.85 system, it was decided that a simple two-element lens of relatively long focal length be used, and the optical path from reticle to lens "folded" by plane mirrors to obtain compactness. An improved electrical method of illuminating the reticle was used, and a system of daylight illumination added.

Due to the fact that the Army and Navy desired different size reticles special instruments had to be designed for each service. These are called Figure 4 sights, because of the shape of the light path.

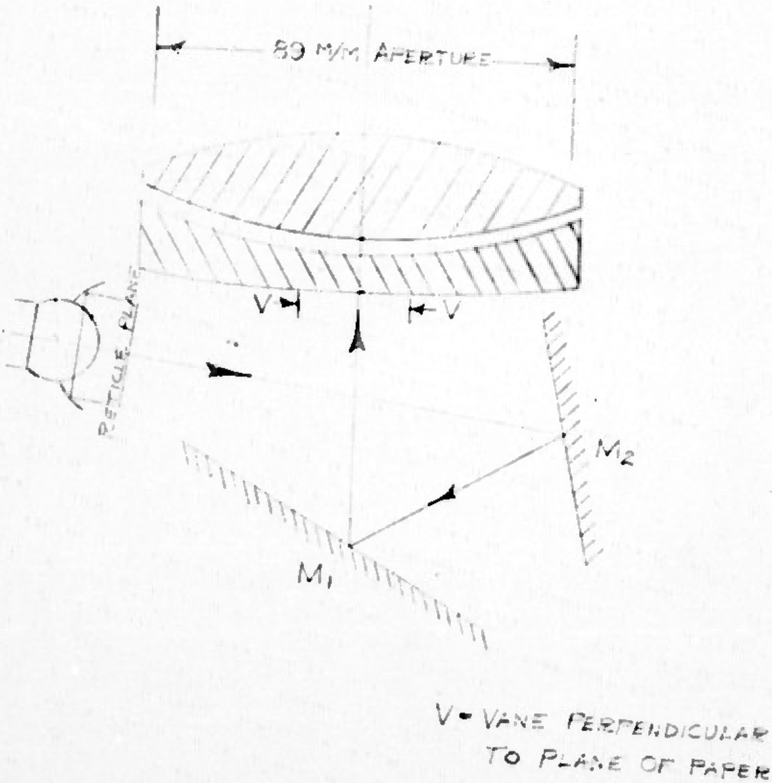
A. Type S-1 (Army N-9)

A single ring of 70 mil diameter and a center dot was the reticle pattern desired by the Army; the tolerance of reticle deviation with movement of the head was given as 1 mil per inch. (The Mark 8 reticle moved 8 mils per inch of head movement.) Therefore, a two-element lens of aperture ratio f/2.5 which can accommodate this reticle size was designed for the projection lens.

Figure 2 shows the optical design of this S-1 sight, full size; plane mirrors, M_1 and M_2, fold the optical path between reticle and lens twice, forming a figure 4. These mirrors are made by aluminizing selected plate glass with no additional optical working; lens elements are made of spectacle glasses which are produced in large quantities; the procurement of large numbers of such a sight is, therefore, relatively easy.

Electrical illumination of the reticle is shown in Figure 3, giving a very brilliant image which can be seen almost up to the limb of the sun. This is accomplished with a 3-6 candle power lamp as compared with 21 c.p. in the Mark 8, and thus develops considerably less heat with less danger of burning out the reticle. Light from the filament F is reflected by the simple spherical mirror M, which can be arranged to concentrate the light in a ring in the plane of the reticle R which also contains the center of curvature of the mirror. The central spot is illuminated by a negative lens L which produces a brilliant virtual image of the filament in the plane of the reticle at C.

One troublesome feature of the folded type of sight is the tendency for confusing reflections to appear in the projected image. This has been effectively eliminated by placing a diaphragm D (see Figure 3) several millimeters outside the reticle, cutting off most of the light outside the desired cone. For the comparatively simple Army reticle, it was most convenient to make the reticle and light shield in one unit as shown; the opening which forms the ring is at the bottom of a V-shaped groove with threaded sides which act as a series of closely spaced diaphragms. The central spot has a single diaphragm outside its illuminating system. Even with this shielding, two small arcs of the ring where still visible by reflection in the last surface



OPTICAL SYSTEM OF S-1 REFLEX - FULL SIZE

FIG. 2

ELECTRICAL ILLUMINATION OF RETICLE
TYPE S-1

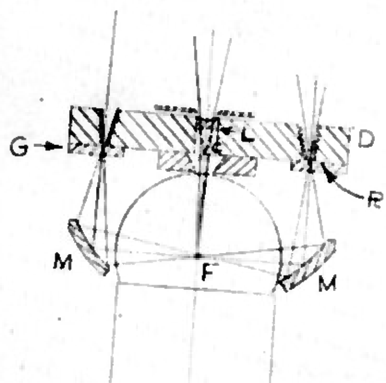


FIG. 3

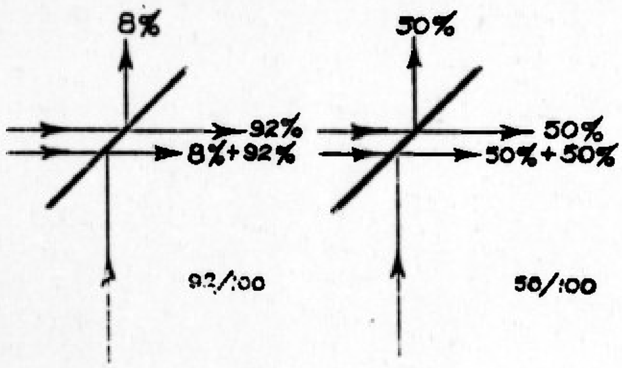
of the lens, but were eliminated by inserting two thin vanes V, shown in figure 2, which appear edge on to the observer and cannot be detected in ordinary use. The reticle ring R, is covered by a piece of glass G with the upper surface ground to diffuse the light.

With the three candle power filament, the projected image is several times as bright as that of the Mark 8, and the illumination appears quite uniform over the whole aperture of the lens.

An alternative method of illumination which utilizes the light of the sky has also been applied successfully. A general theorem of photometry states that no optical device can increase the apparent surface brightness of an extended area over that which would be observed by the unaided eye. Therefore, if reticle lines are to be illuminated by the sky, they cannot be made to appear brighter than the sky itself, and unless the lines are seen against a sky of reduced brightness they will have no contrast and thus will be invisible.

In this case it is necessary to substitute for the clear glass reflex plate one which has been so treated that its transmission and reflection are each approximately 50 per cent. Such plates have been developed at the Institute of Optics for this purpose. Alternate layers of high and low index materials, that have no appreciable absorption for visible light, are coated on a glass plate. When the reflection is built up in this way, true 50-50 plates can be made, while if a "half-silvered" mirror is used about 20 per cent of the light is lost by absorption in the metal. They accomplish the double purpose of reducing the brightness of the sky background to one-half while the brightness of the reticle, illuminated by full sky background (intensity I) through a ground glass is at full intensity. Figures 4a and 4b show the

Difference in intensity contrast with a clear glass and a 50-50 plate.



(a) clear glass

(b) 50-50 plate

Contrast due to reflex plate coating

Figure 4

Daylight illumination has several advantages. It is, of course, more reliable than electrical illumination which is subject to power failure. Moreover, the brightness of the reticle image is automatically adjusted to a constant contrast with the sky against which it is seen. In this case the reticle ring is readily visible even when the sight is pointed directly at the sun, a matter of importance, since an enemy plane frequently attempts to approach in the path of the sun.

At night, both the electrical illumination and uncoated glass reflex plate must be replaced; provision is made for easy changing of the illumination system.

The optical parts of the type S-1 were placed in a wooden mockup (Fig. 5)

Figure 5

Type S-1 Reflex Sight

and brought to Captain Ryan, AAF Materiel Center at Wright Field, on August 15, 1942, and the optical design left with him. He expressed great satisfaction with the electrical illumination, but was somewhat skeptical about the daylight system. It was agreed that the production mechanical design would be left up to the manufacturer if the sight were produced for use. This has now gone into production in substantial quantities as the AAF, N-9 sight.

b. Type S-2.

The Navy S-2 sight is similar to the S-1, but designed for the larger and more complicated Navy reticle, which requires two concentric circles of 100 and 200 mil diameters and 4 radial lines, starting 25 mils from the center and extending to 150 mils. It uses an f/3.0 lens, which can accommodate a reticle 200 mils square; this is sufficient if the radial lines are placed on the diagonals of the square.

For illumination of the S-2 reticle, the system used in the type S-1 could not be employed, because it did not illuminate the radial lines sufficiently well. Thus the illuminator of the S-2 type consists simply of a lamp in an enclosure with highly reflecting walls; the central spot is illuminated by a negative lens as before. Another method of illuminating the reticle more uniformly was worked out in July 1942, using a system of semi-cylindrical lenses on the back of the reticle plate but this did not go into production. Daylight illumination is as effective in the S-2 as in the S-1 sight.

Several samples of this instrument were ordered from the Preston Laboratories in January, 1943, by the Navy Bureau of Ordnance.

C. Type S-3.

A third type of aircraft reflex sight was designed at the Institute of Optics differing from the other two in that it uses a solid plastic optical system. This makes it less bulky than the S-2, for a solid optical system has the advantage that the focal length in 1/n times as long as an air system and the apparent diameter of the projected reticle pattern is n times as large (where n is the index of refraction of the plastic). Thus the 100 mil ring in the Navy reticle pattern would require an actual ring of only 67 mils.

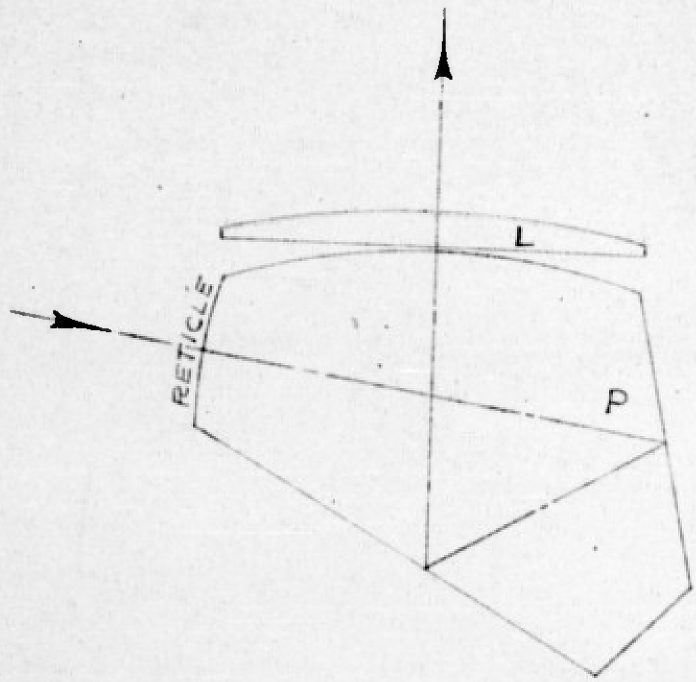
Figure 6 shows the full scale design of the type S-3. A single lens of spectacle crown glass L is used with a prism P of methyl methacrylate which has one lens surface and a curved reticle surface. The dimensions of the system are comparable with S-1. The illumination is identical with the S-2 sight.

Samples of the S-3 type were made for the Navy BuOrd by Preston Laboratories, Butler, Pa., at the same time as the S-1. These have not been inspected at the Institute of Optics, but the Navy reports that they were unsatisfactory because it was impossible to obtain large blocks of plastic of sufficiently good optical quality.

III. Radar Reflex Sight (Flight Sight).

At the request of Lt. Commander Taylor, USN, a conference was held at the Radiation Laboratory, Massachusetts Institute of Technology, in June, 1942, to discuss the design of an optical sight to be used in conjunction with Radar in Navy single seater night fighter planes. Representatives of the Naval Bureau of Ordnance, the Radiation Laboratory and the Institute of Optics attended.

The purpose of this sight, called the "flight sight", was to permit the



REFLEX SIGHT S-3

FIG. 6

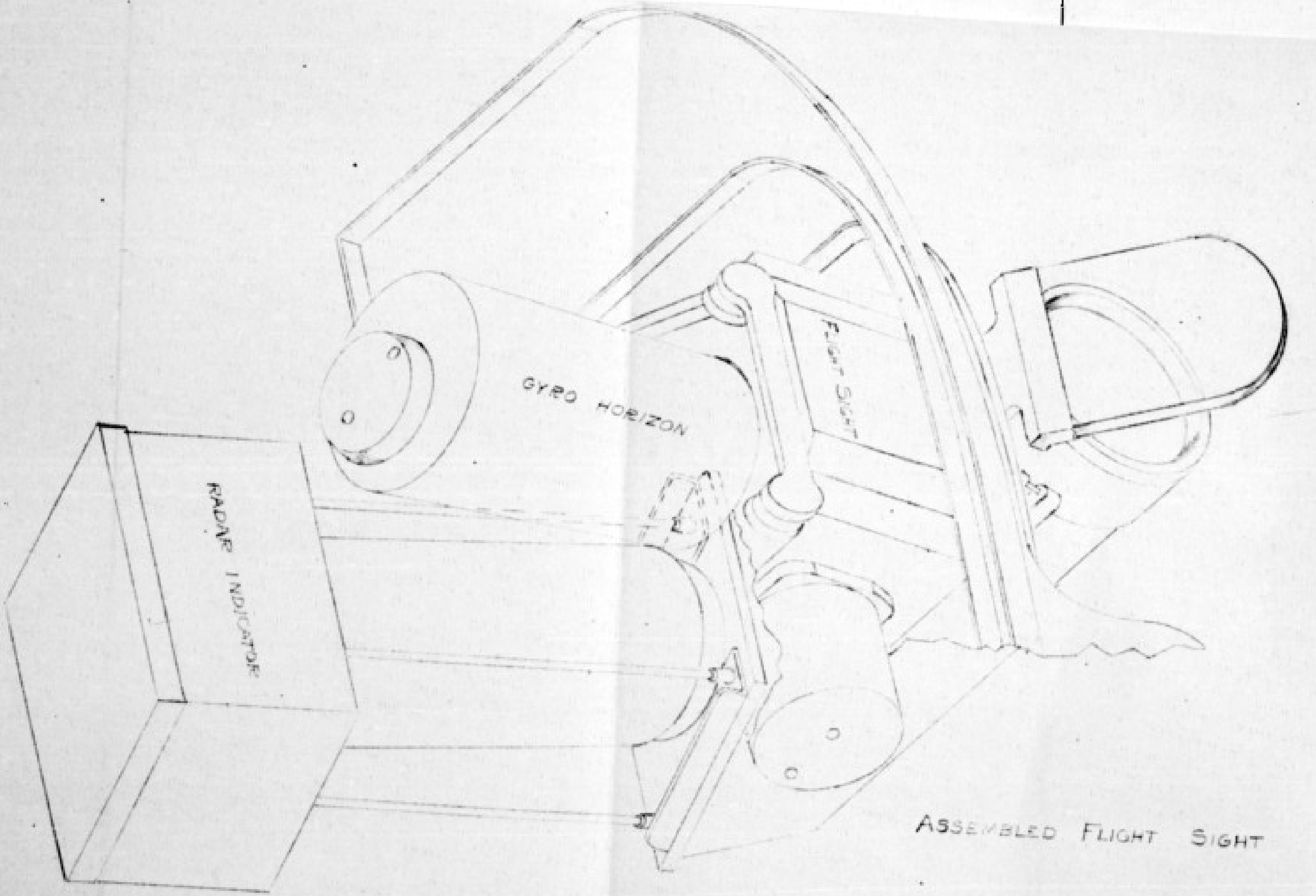
pilot of a single seater plane to search visually and with radar for enemy planes, and at the same time to have before him instrument indications which could be seen without alteration of eye accommodation and with a minimum of damage to dark adaptation. It was decided that the pilot should be able to see images projected at infinity against the sky of :

1. A reticle for aiming the guns.
2. The face of the radar oscilloscope screen.
3. The indication from a gyrohorizon.
4. The indication from an airspeed meter.
5. A bright reticle for use in day fighting.

With these images visible in the reflex plate, the pilot intercepts and attacks an enemy without need to refer to any other instruments. The Navy requested that the sight be designed specially for an F4U-2 plane, which would not be ready for inspection until September, but that the first sample be adapted for use in a JRB airplane. Size should be held to a minimum, and the sight should be suitable for both night and day use. Duplicate instruments to those already on the instrument panel could be used if necessary.

After an inspection of the F4U-2, a specific design and wooden mockup of the flight sight were made. In November, these were discussed with officers at the Naval Air Station, Quonset Point, R.I., and slight changes made. It was agreed that the sight should be built so as to fit over the radar oscilloscope in the instrument panel, with provision allowed for viewing the radar screen directly as well as with the reflex plate. An auxiliary gyro horizon and airspeed indicator could be included in the instrument.

A drawing of the assembled sight placed over the radar scope is shown in Figure 7; Figure 8 gives an isometric view of the method of projecting the



ASSEMBLED FLIGHT SIGHT

FIG. 7

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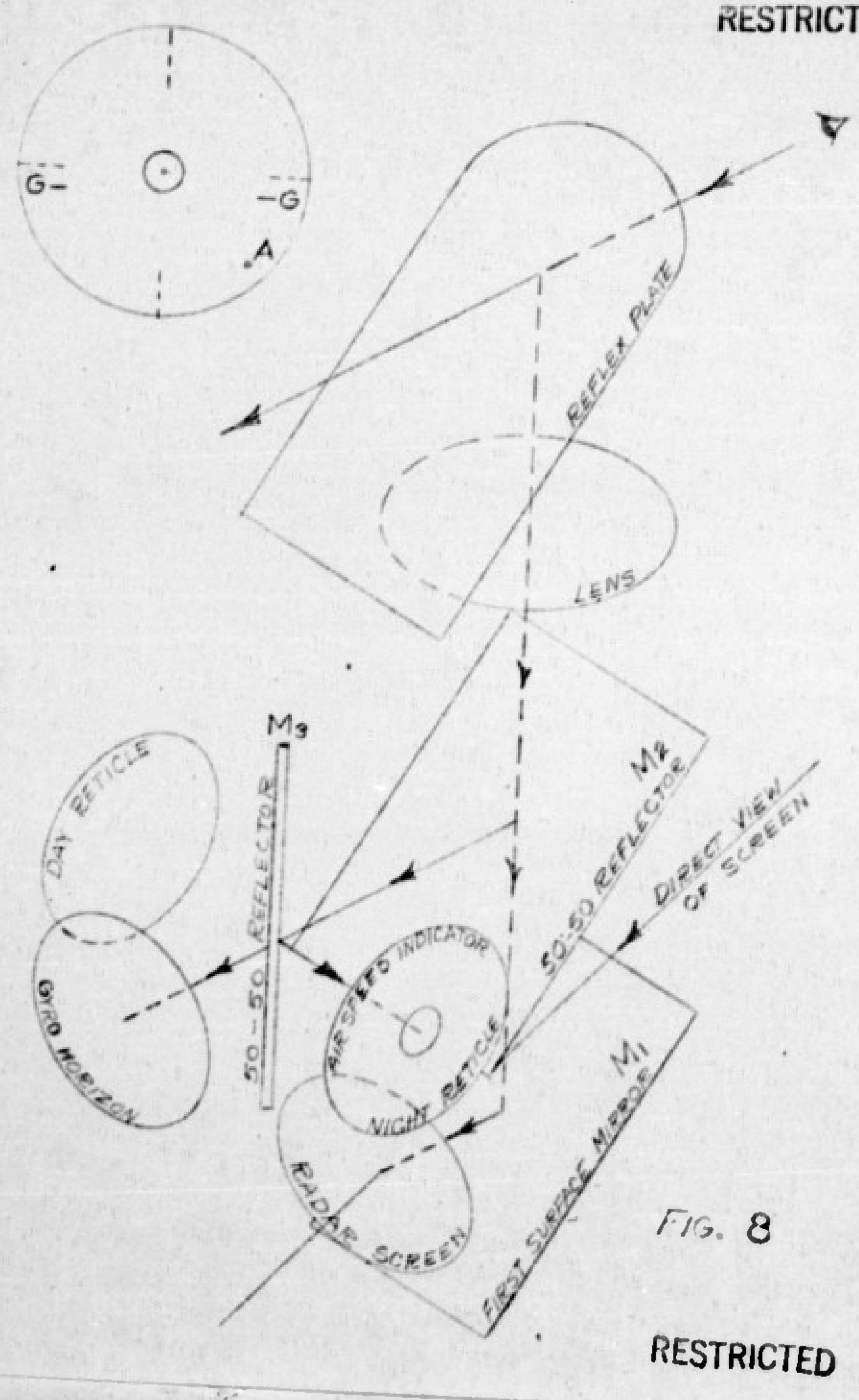

FIG. 8

RESTRICTED

various images, with the field pattern shown in the upper left-hand corner. Light from the radar screen is reflected by the mirror M_1 through the semi-transparent plate M_2 and projection lens to the reflex plate and thence to the eye. The gyrohorizon light passes through the semi-transparent plate M_3 and is reflected at M_2; the airspeed indicater light is reflected first at M_3 and then at M_2.

In front of the airspeed indicator a night reticle is placed with a circle in the center of 25 mils diameter which serves as an aiming spot and the zero of coordinates for the radar pip. Four fixed graduations at the cardinal points act as reference points for the tips of the horizon bar G of the gyro horizon and the hand A of the airspeed indicator, seen at the edge of the field; the two indicators rotate concentricly with the aiming ring. The radar screen covers the circular area shown on the field view. For day use, the semi-reflector M_3 is rotated by ninety degrees so that it reflects the image of an illuminated reticle of the conventional Navy pattern. Figure 9 shows photographs of the completed flight sight.

The construction of the instrument was completed in the last week of March and the sight taken to Quonset Point on April 5, 1945. No further report was made to the Institute of Optics until August, 1944, when two representatives were asked to attend a flight test at Patuxent River Naval Air Station. In a Navy report dated the 21st of August, 1944, the results of this and succeeding tests in a JRB plane are given. First tests were made using a plain glass reflex plate, but this did not give sufficient intensity of the radar indicator; a second reflex plate of 50 per cent reflection was apparently satisfactory. The total weight added to the airplane by the use of the flight sight was approximately 12 pounds, which the Navy desired to reduce. Radar

Restricted

Flight Sight

Figure 9

Restricted

mapping appearing in the sight was satisfactory for both range and azimuth, but elevation could not be determined because the two dots used for this purpose blurred into one badly focussed spot due to vibration of the instrument. Tests at the Institute of Optics showed the mounting of the reflex plate to be at fault, and that a simple brace would remedy the condition. The airspeed indicator and gyrohorizon were considered very helpful to the pilot.

IV. Reflex Sight for A-A Gun.

In July, 1943, the Institute of Optics was asked to design two reflex sights to replace the unit power telescopic sights in the M-7 lead computer on the 40 mm Bofors anti-aircraft gun. The special requirements were as follows:

a) Deviation of the reticle image less than 1 mil, as the eye moves from the center to the edge of the field.

b) An eye circle (area in which complete reticle image can be seen) at least 35 mm in diameter.

c) A reticle pattern consisting of a single line 100 mils long, seen horizontal in the elevation sight and vertical in the azimuth sight.

d) The moment of inertia about the point of support, 20 centimeters below the line of sight, held to a minimum to decrease the deflection of the sight due to recoil of gun.

e) Dimensions and fitting suitable for mounting the sight on the existing M-7 lead computer.

Three 40 mm aperture sights with a focal length of 120 mm, model 5407, ser. 01,02 and 03 were designed and built at the Institute of Optics. These were identical in the main body of the sight, but differed in the method of illumination. The principal features are shown in Figure 10, where the main body of the sight is included on the left and the illumination system of scr. 05 is shown on the right of the dotted line D-D.

The principal source of illumination in all three sights is the sky in the immediate neighborhood of the target. Light from this portion of the sky is brought to the reticle plate, G, around various parts of the lead computing mechanism by a carefully designed lens and prism system. The construction of the M-7 lead computer is such that the azimuth sight is mounted directly behind a box, B, containing the lead setting mechanism, with the line of sight barely clearing the top of the box. The altitude sight was similarly obstructed, but to a lesser degree. Sky illuminators, therefore, which must utilize light from a horizontal strip of sky containing the target (in order to ensure constant contrast) had to be designed so that the light entered through a prism P located just below the lower edge of the reflex plate.

As in the previously described sights, both surfaces of the reflex plate R are coated with a partially reflecting film, in order to raise the contrast between the sky illuminated line and the sky itself as seen through the plate. This simple method of illumination gives a very conspicuous line which maintains its contrast against the brightest sky and can be seen right up to the limb of the sun if the observer can stand the eye strain. It has the further merit of being unaffected by any failures in an electrical circuit, which, on a hand operated gun with no built-in electrical system, is of considerable importance.

Figure 11 shows the optical systems for the altitude and azimuth sights; they differ only in the erecting prism (2) of the azimuth sight which gives a vertical image of the horizontal strip of sky from which the light comes.

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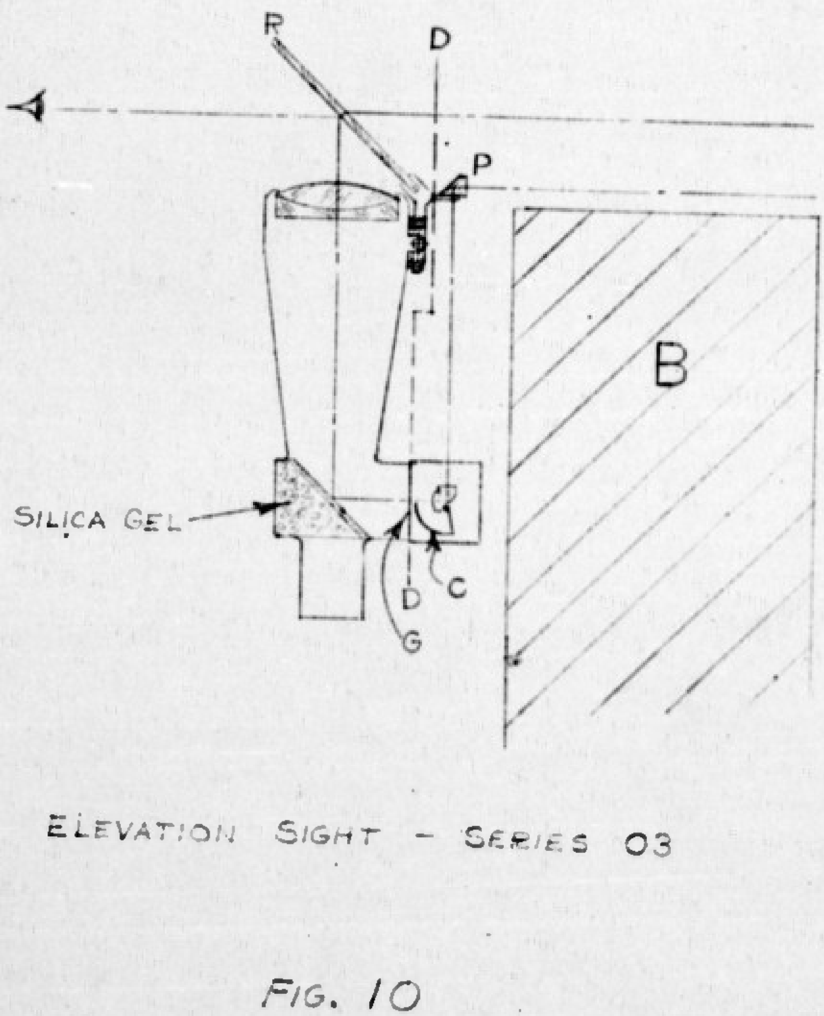

ELEVATION SIGHT - SERIES 03

FIG. 10

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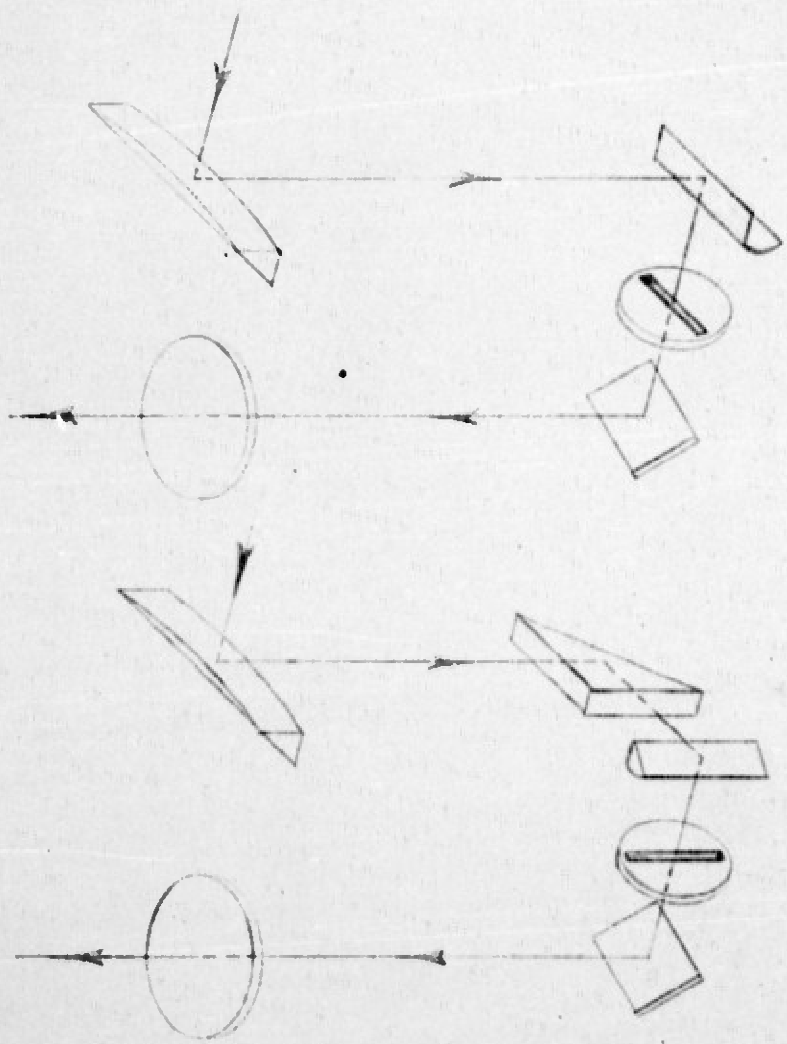

AZIMUTH SIGHT ALTITUDE SIGHT

DAYLIGHT ILLUMINATION SYSTEM

FIG. 11

In order to fill the objective lens without resorting to large and cumbersome prisms, two crossed cylindrical lenses were used. These were ground directly on the faces of prisms 1 and 3. The function of the cylindrical surfaces is apparent in Figure 12, which shows the optical system straightened out by omitting the plane reflecting surface. The two drawings represent the system in planes parallel and perpendicular to the reticle slit.

In addition to the sky illumination, the three sights are equipped with auxiliary illumination for use at night. In sights 01 and 02 the auxiliary system is electrical and is made sufficiently bright for day use. Change over from daylight to electrical illumination is accomplished in series 01 (azimuth sight) by sliding prism 3 (Figure 11) out of the beam, permitting light from the lamp filament to reach the slit via the cylindrical mirror. In series 02 (elevation sight) the change over is accomplished by simply screwing the illuminator in place; sky illumination is obtained by exposing the reticle to the open sky. When this sight was first tried on the gun, it was found that the sky was partially obstructed and for this reason a prism system is used in series 03 (elevation sight).

A preference for sky over electrical illumination for day use was expressed by the AAA board upon examination of series 01 and 02, and, therefore, another night system is used in series 03, that of a much fainter radium excited fluorescent illumination. The fluorescent material (U.S. Radium Corp. #253a) is coated over the cylindrical surface C (Figure 10) and covered with a wedge of plastic binder varying from zero to 0.008 inch. This cylindrical surface can be rotated about its axis by means of an external knob so that it can be turned entirely out of the optical system, for day illumination, or any part of the coated surface brought into position behind the reticle slit for night use. The brightness of the fluorescence varies with the thickness of the

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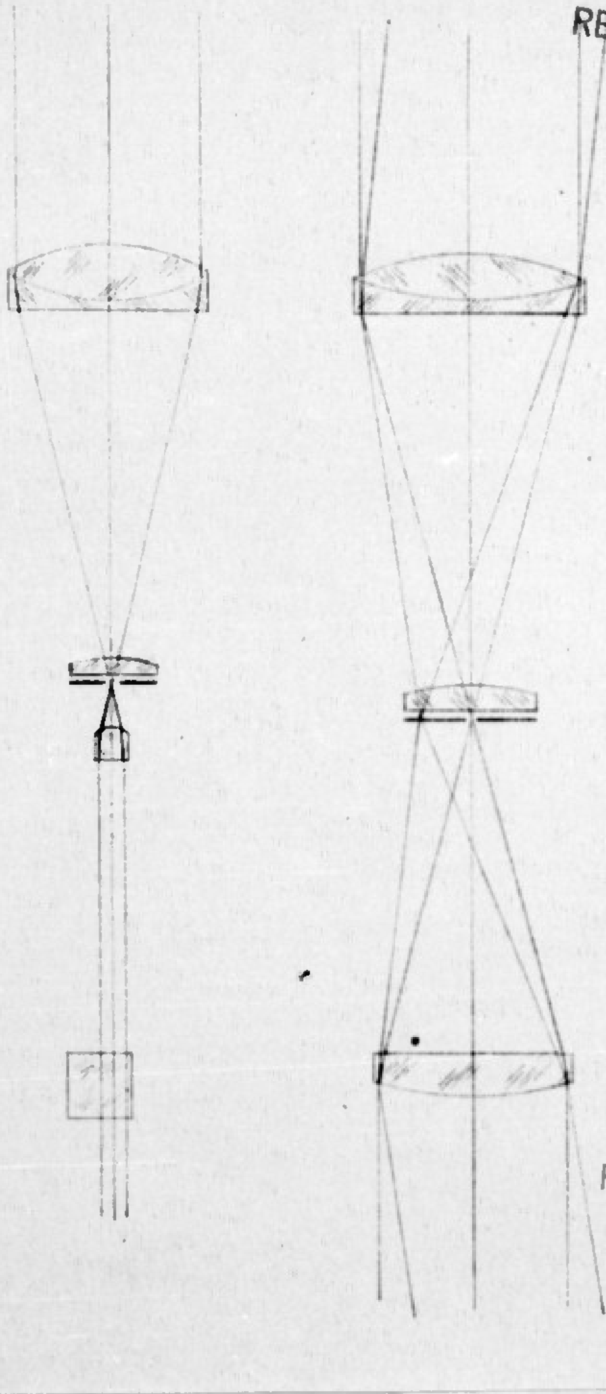

FIG. 12

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Azimuth Sight Ser.01

Elevation Sight Ser.02

Elevation Sight Ser.03
Figure 13

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plastic covering which absorbs part of the energy of the radium α particles which produce the fluorescence. This provides a satisfactory means of adjusting the reticle brightness over a range of about 100 to 1.

The source, made by the United States Radium Corporation, consists of radium rolled in gold foil of about 3 microns thickness and supported on a silver backing 125 microns thick, with the concentration of radium 0.20 mg/cm^2. This high radium concentration, necessary to obtain the desired brightness in the fluorescent surface, would destroy the phosphor in a few weeks if it were permanently exposed to the alpha particle bombardment. Therefore, the radium impregnated foil is mounted in a narrow strip on each side of the reticle slit and bombards only the phosphor directly behind the slit; when not in use the phosphor is swung away.

Photographs of the three models are shown in Figure 13. By February, 1944 all three sights were delivered to Lt. Colonel Nesmith, of the AAA Board, Camp Davis, N.C., for testing. These sights are now in substantial production by two manufacturers, and are known as the M-21, M-22, M-23 and M-24, respectively.

V. Reflex Sights for 40 Caliber Machine Gun and Maxson Gun Turret.

At the request of Major F. S. Brackett, Armored Medical Research Laboratory, Fot Knox, Ky., a reflex sight was developed for a 50 caliber machine gun, to be mounted on both 6 x 6 and half-track trucks. While this sight was being developed, another request came from Camp Davis (Lt. Col. Nesmith), for a sight to determine the aim of the 50 caliber guns in a Maxson anti-aircraft turret, to replace their type M-9. This needed the same optical system but a slightly larger reticle than the machine gun sight.

The original sight designed for Ft. Knox used an optical system with an f/2 lens of 50 mm aperture and a curved reticle of 51.8 mm radius. A pattern of concentric rings was traced on the reticle, with the largest of radius 210 mils. The displacement of a point in the center of the field was less than half a mil as the eye moved over the complete aperture, and less than one mil for points on the 210 mil ring. There was no perceptible lateral color even in the largest ring. Daylight illumination was used with provision made for clamping on an electrical illumination system for night use.

It was desired to have the eyepoint fixed in space so that the operator would not be required to rise and crouch depending on the direction of the gun. Also, the line of sight should be from 14 to 18 inches above the line of fire in order to allow sighting over the smoke of the muzzle blast. A difficulty arose due to the changing distance between the eyepoint and the handles of the gun as the barrel was raised and lowered, making it hard for the operator to keep his head in the eyepoint position and at the same time keep a firm grip on the handles. A compromise was achieved between a fixed eyepoint and a fixed distance between eyepoint and handles by mounting the sight on a wooden parallelogram which changed its angles with the movement of the gun (by pressure on the head rest) and allowed comparatively easy sighting. The mount was such that boresighting could be maintained to within 5 mils during the firing of the machine gun.

This sight was completed in February, 1944, and demonstrated with the wooden parallelogram in firing tests at Fort Knox. The accuracy of aim was much better with the sight than without it and the basic problem was considered solved. The same sight without the wooden mount was shown to the group at Camp Davis on the Maxson turret, also in February, with favorable results. It was decided that while a new metal parallelogram (see supplement) was being constructed for the Fort Knox sight, the aperture of the lens system could be increased to 60 mm to incorporate a 280 mil radius ring desired at Camp Davis; this would also allow a longer eye relief for the machine gun use, and would require no change in the lens system except in diameter.

The final instrument was completed in July, 1944. Figure 14 shows the optical design, and Figure 15 photographs of the sight and parallelogram. A new mounting takes care of lateral as well as longitudinal vibrations during firing, the parallelogram being mounted on the gun through a spring steel cantilever. The Ft. Knox group also made a mount to their own design. At Camp Davis the new sight was received with enthusiasm, and it is now in substantial production.

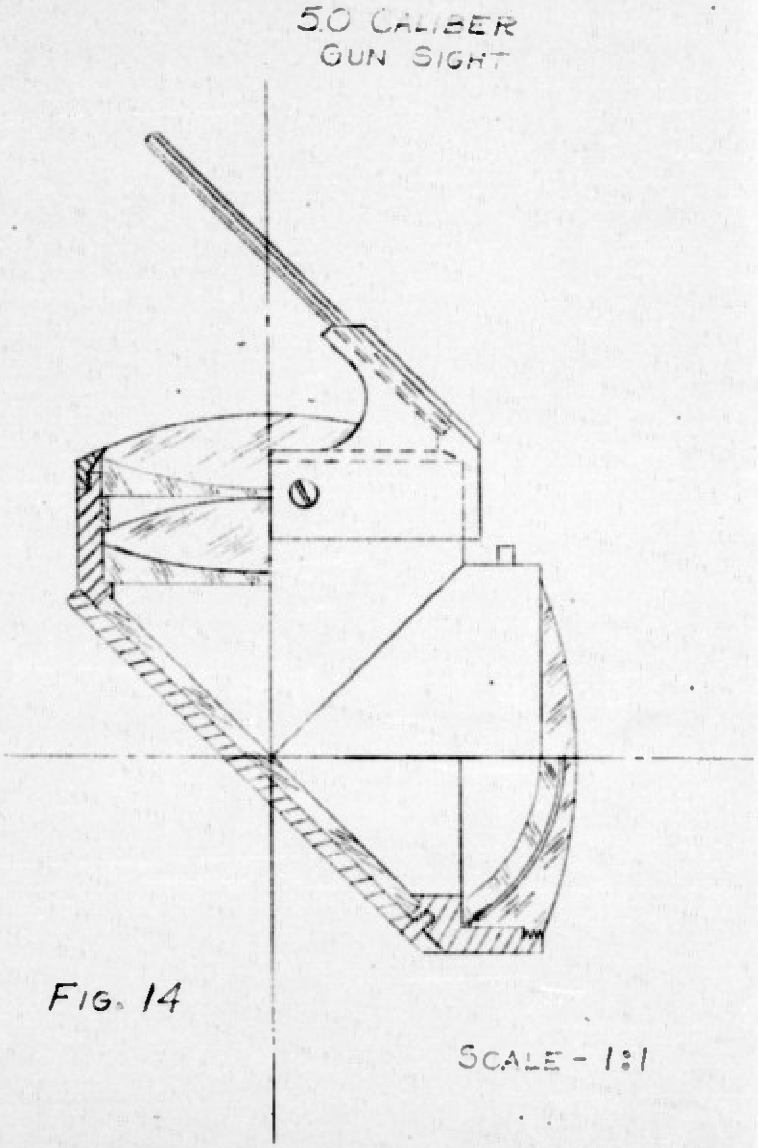

FIG. 14

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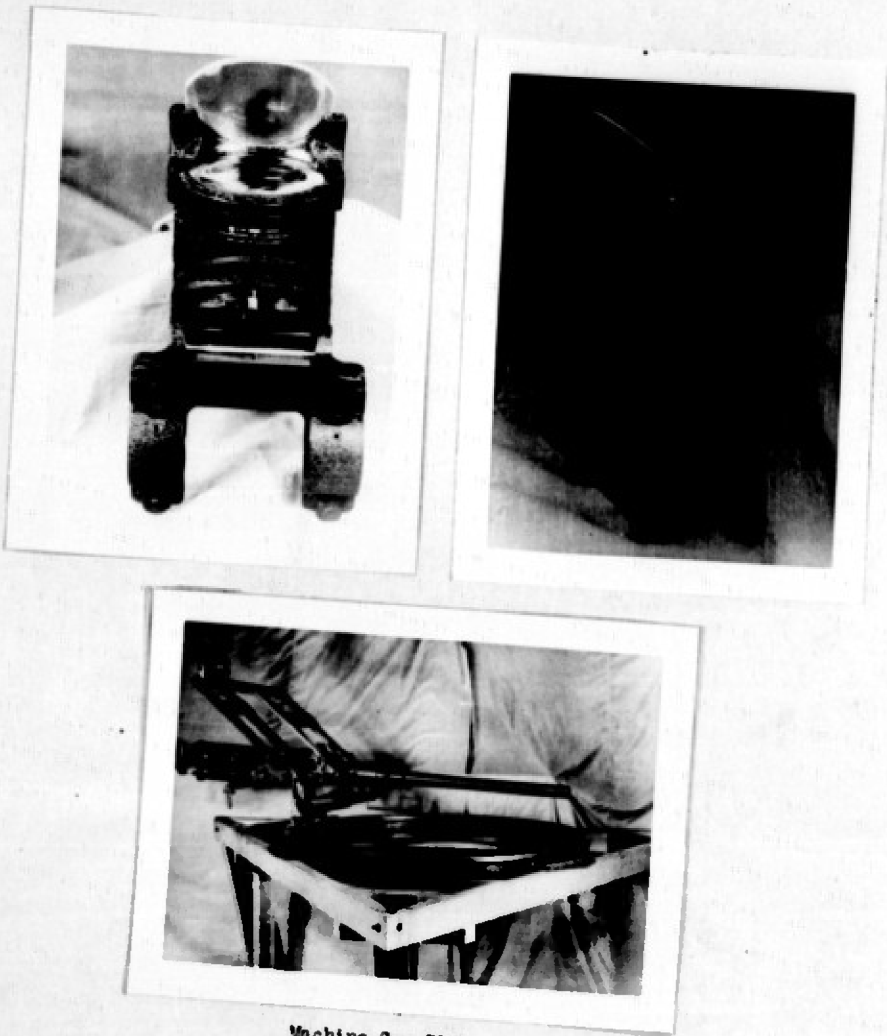

Machine-Gun Sight

Figure 15

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SUPPLEMENT

DESCRIPTION OF

PANTOGRAPH SIGHT MOUNT FOR THE 50 CALIBER FLEXIBLE MACHINE GUN

At the time this mount was conceived, 50 cal. AA machine gun fire control consisted essentially of individual tracer observation. The use of the standard sights provided on the 50 cal. g uns was impossible because of the smoke cloud and heat eddies formed during the firing of even a short burst. Since tracer observation is an inefficient method of fire control for AA work against strafing aircraft, some method of mounting a small reflex sight approximately 20" above the line of fire was deemed worthy of trial.

The construction decided upon consisted of a parallelogram made up of two pairs of arms holding a rectangular platform about 17" over the gun barrel and attached to the gun barrel and receiver. These arms were mounted in low-friction bearings at all eight points of attachment, thus allowing the parallelogram to alter its shape as the gun was elevated or depressed. A second small parallelogram served as a link between this main sight mount and the swivel gun mount for the purpose of maintaining the sight in a relatively fixed position in space. Th8s "control link" parallelogram differed from a true parallelogram in two respects; first, one arm consisted of a leaf spring to lend resiliency to the mount, and second, another arm was made of adjustable length to allow adjustment of the neutral position and travel of the main unit. Figure 16 shows a design drawing of the parallelogram.

The sight mounted on this elevated mount was of the daylight-illuminated reflex type having a wide aperture permitting lead rings of 300 mph to be seen. A headrest was provided on the mount for increased gunner comfort. Figures 17-20 compare the ease of viewing with the parallelogram mounting and with a fixed mounting.

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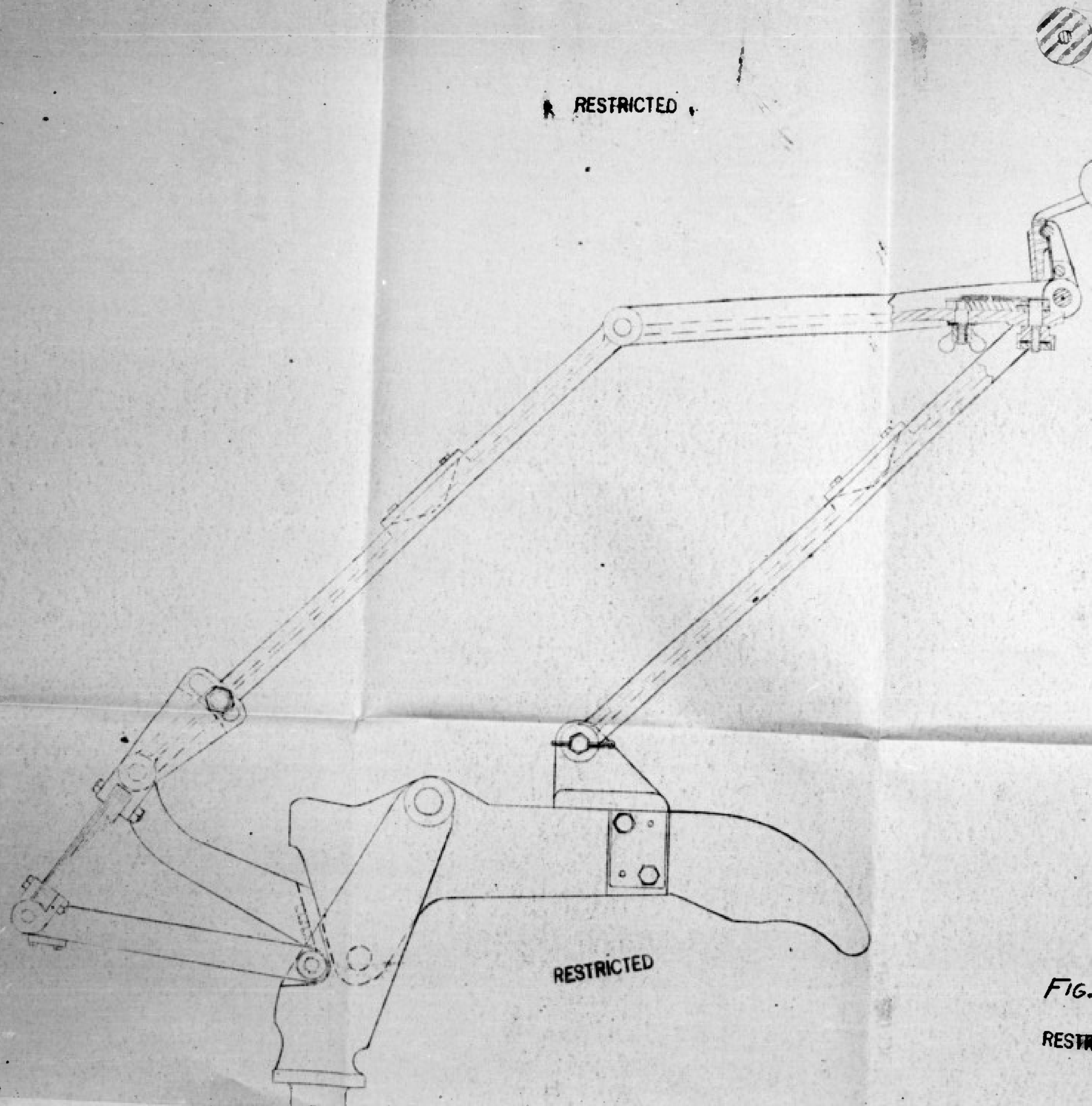

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FIG. 16

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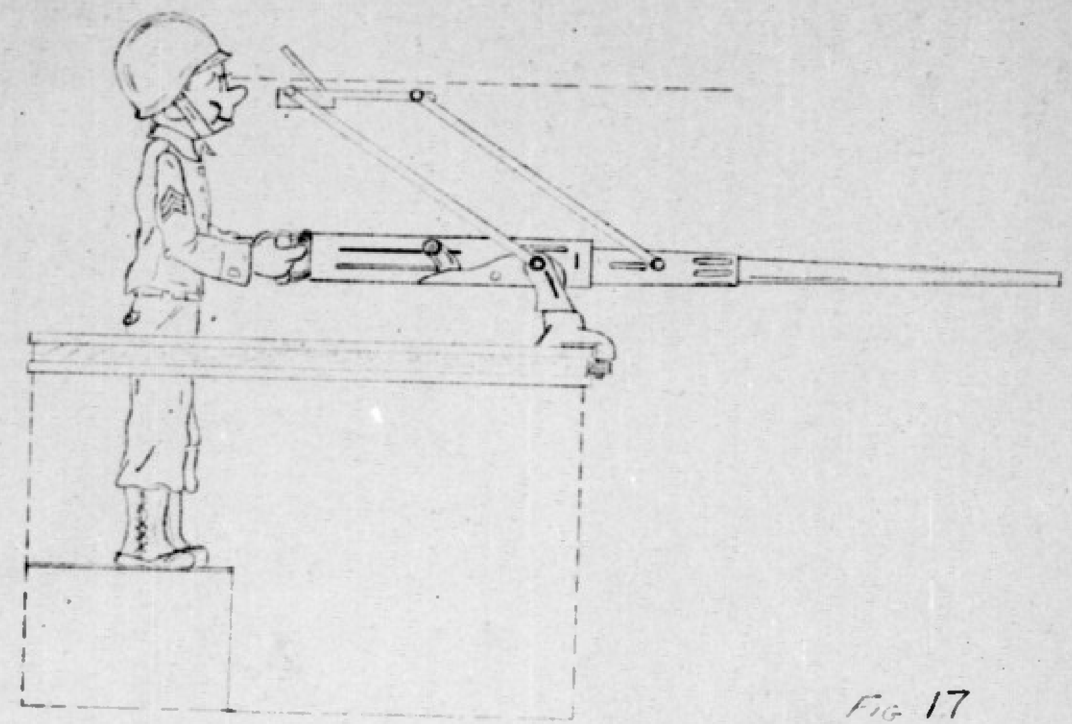

Fig 17

Edw. Palmer

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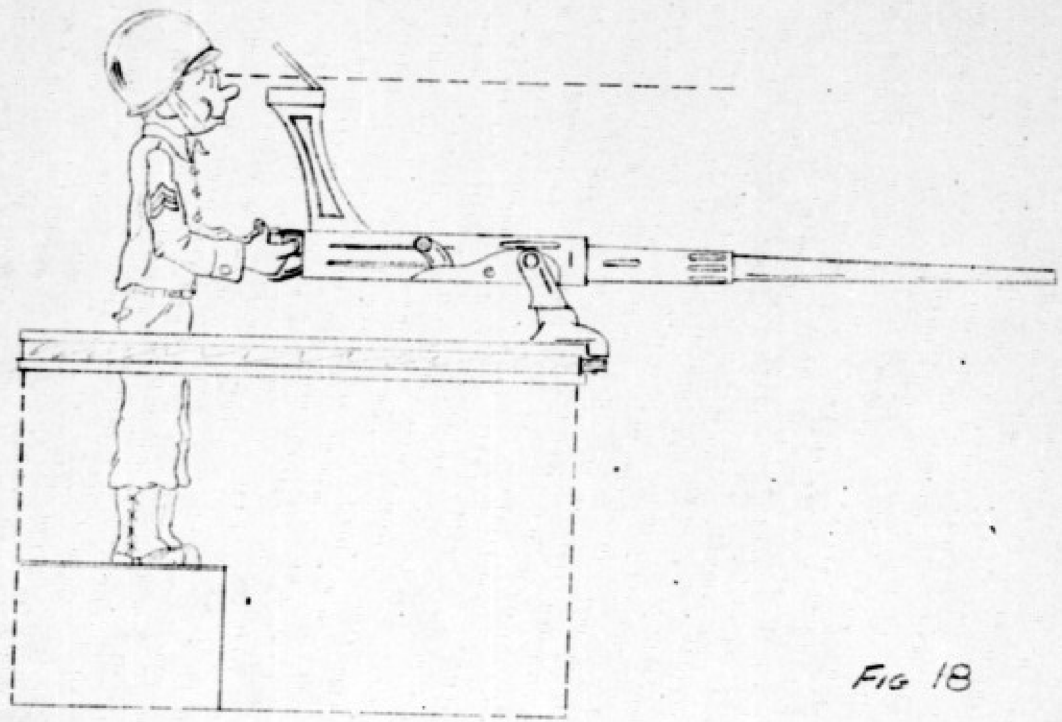

Fig 18

Edw. Palmer

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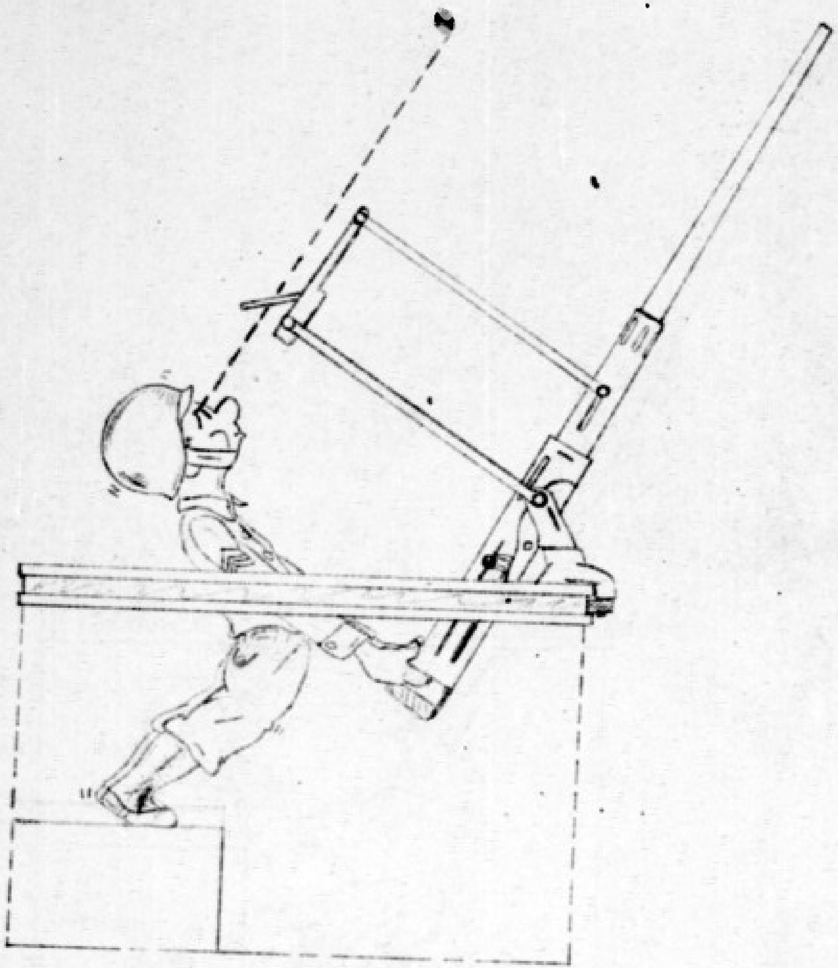

Fig 19

Edw. Pate

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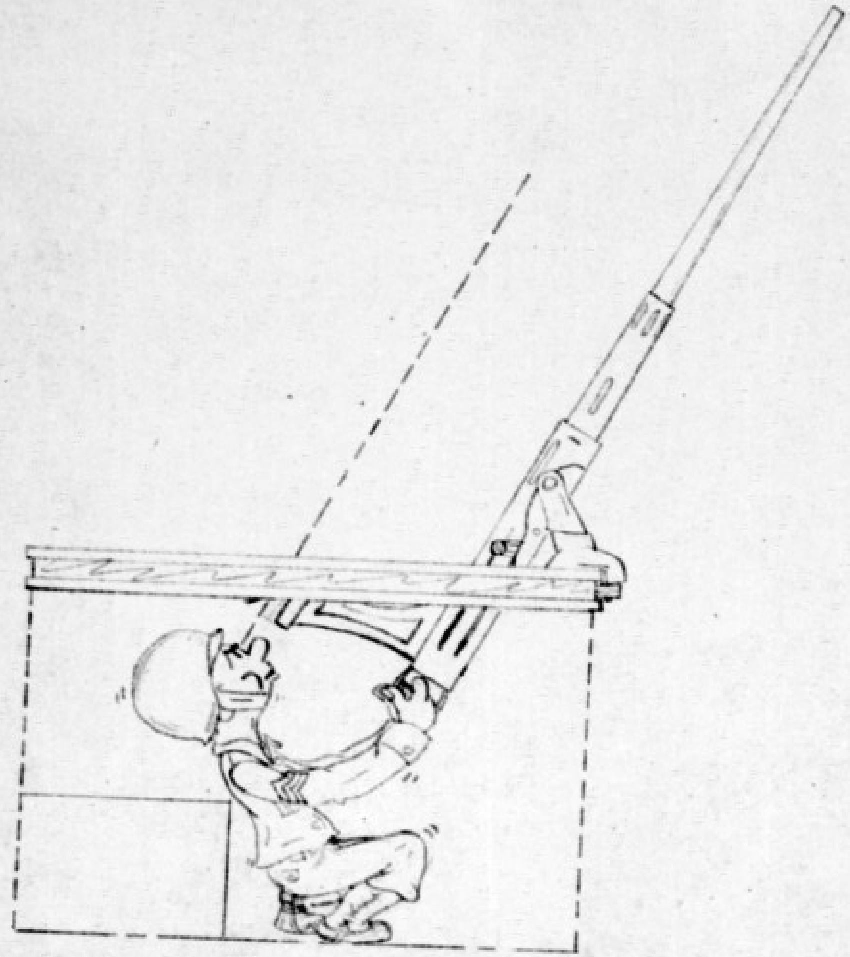

FIG 20

Edw. Palmer

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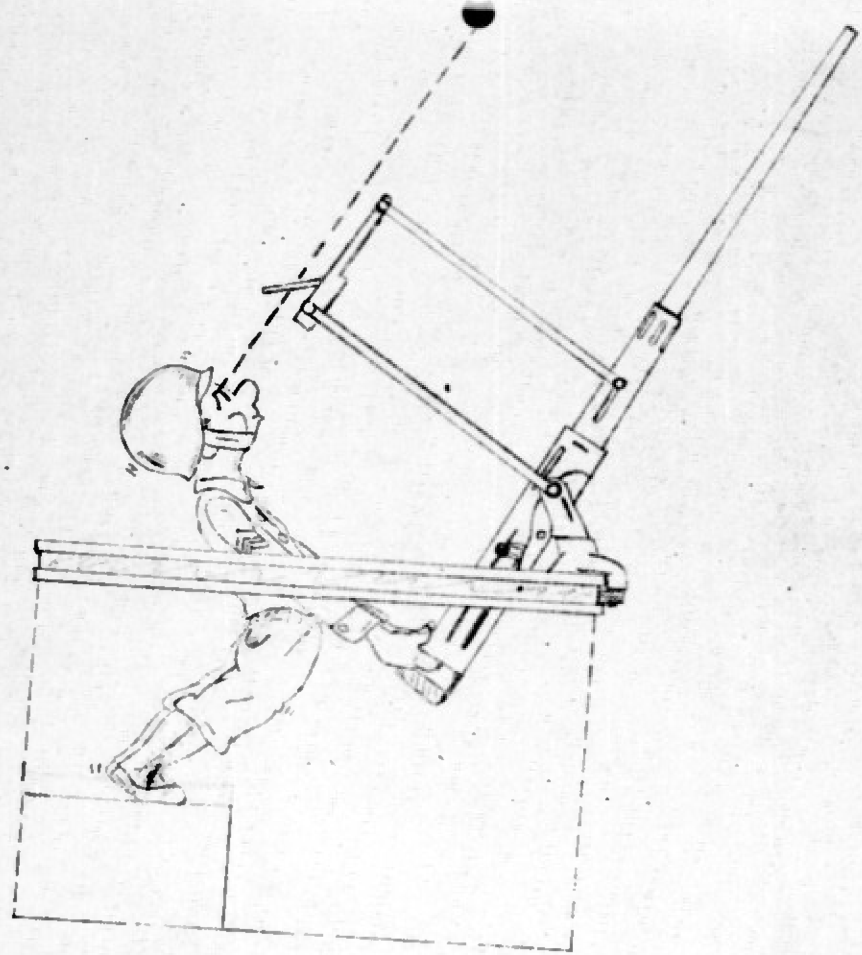

Fig 19

Edw. Patw

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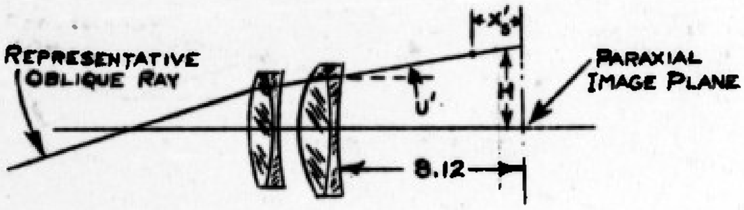
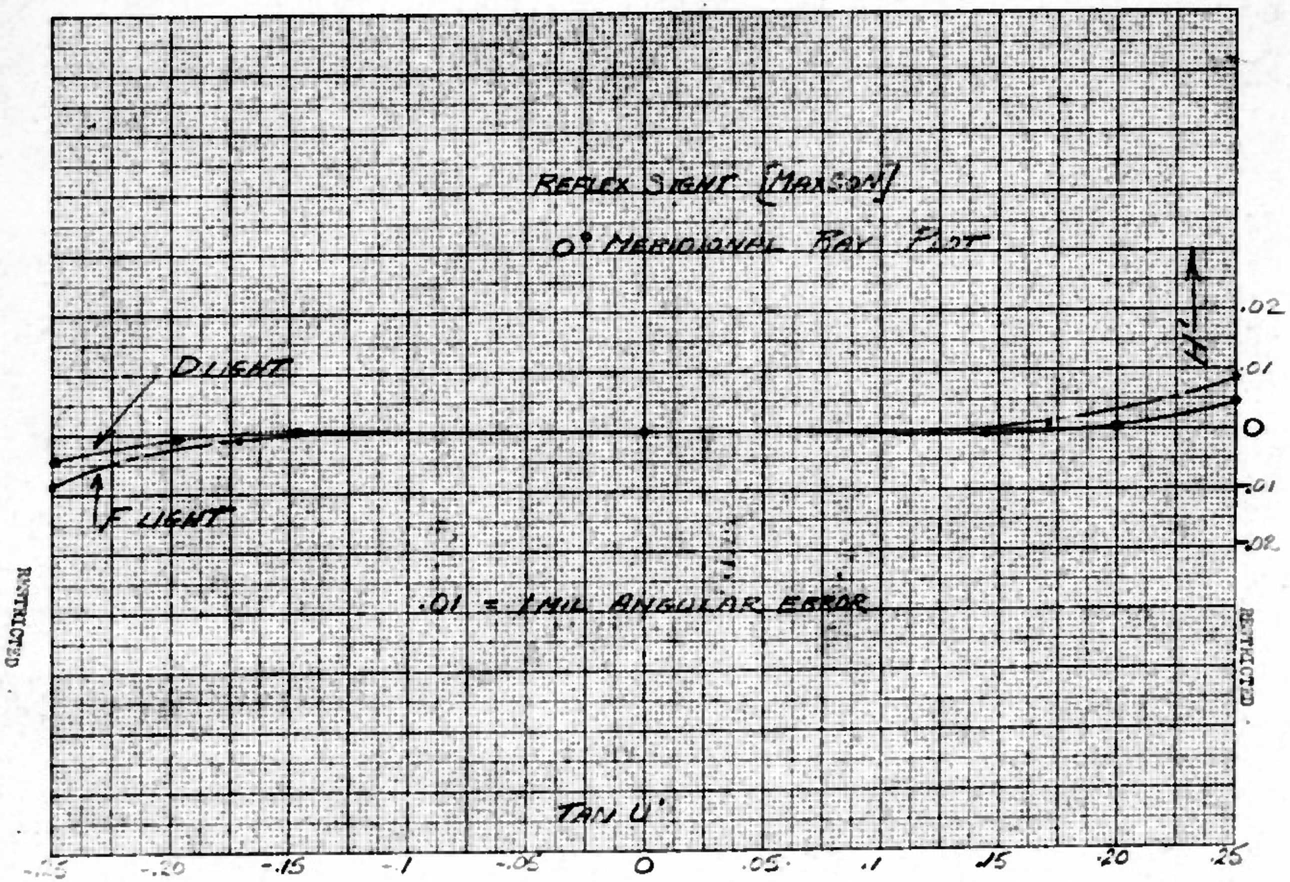
ADDENDUM TO REPORT ON REFLEX SIGHTS

The following diagrams are meridional ray plots for the Maxson reflex sight. Along the ordinate is plotted the height that a ray strikes the 0 degree paraxial ray image surface; this plane is 8.12 cm from the back surface of the lens. Along the abscissa is plotted the angle the ray makes with the axis. The following diagram illustrates the notation used.



It should be noted that the oblique meridional ray plots are sloping, indicating that the field is inward curving toward the lens. X_s' is the horizontal distance from the paraxial image plane to the close sagittal ray image. The reticle surface was curved to focus the meridional rays. The final graph shows the results of testing a sight. This plot shows the overall performance of the instrument with the reticle focussed in the optimum position.


REFLEX SIGHT [MAXSON]
0° MERIDIONAL RAY PLOT
.01 = 1 MIL ANGULAR ERROR
D LIGHT
F LIGHT
H'
TAN U'
.02
.01
0
.01
.02
-.25
-.20
-.15
-.1
-.05
0
.05
.1
.15
.20
.25

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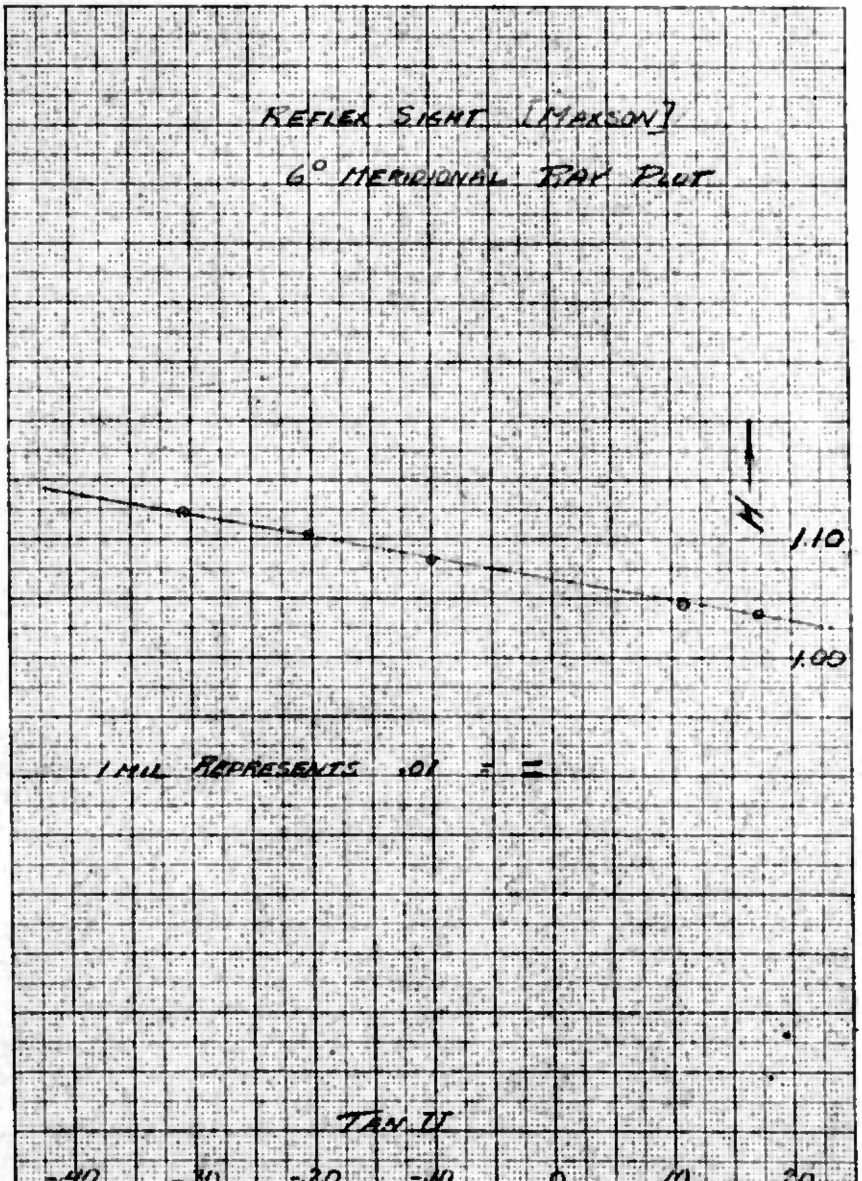

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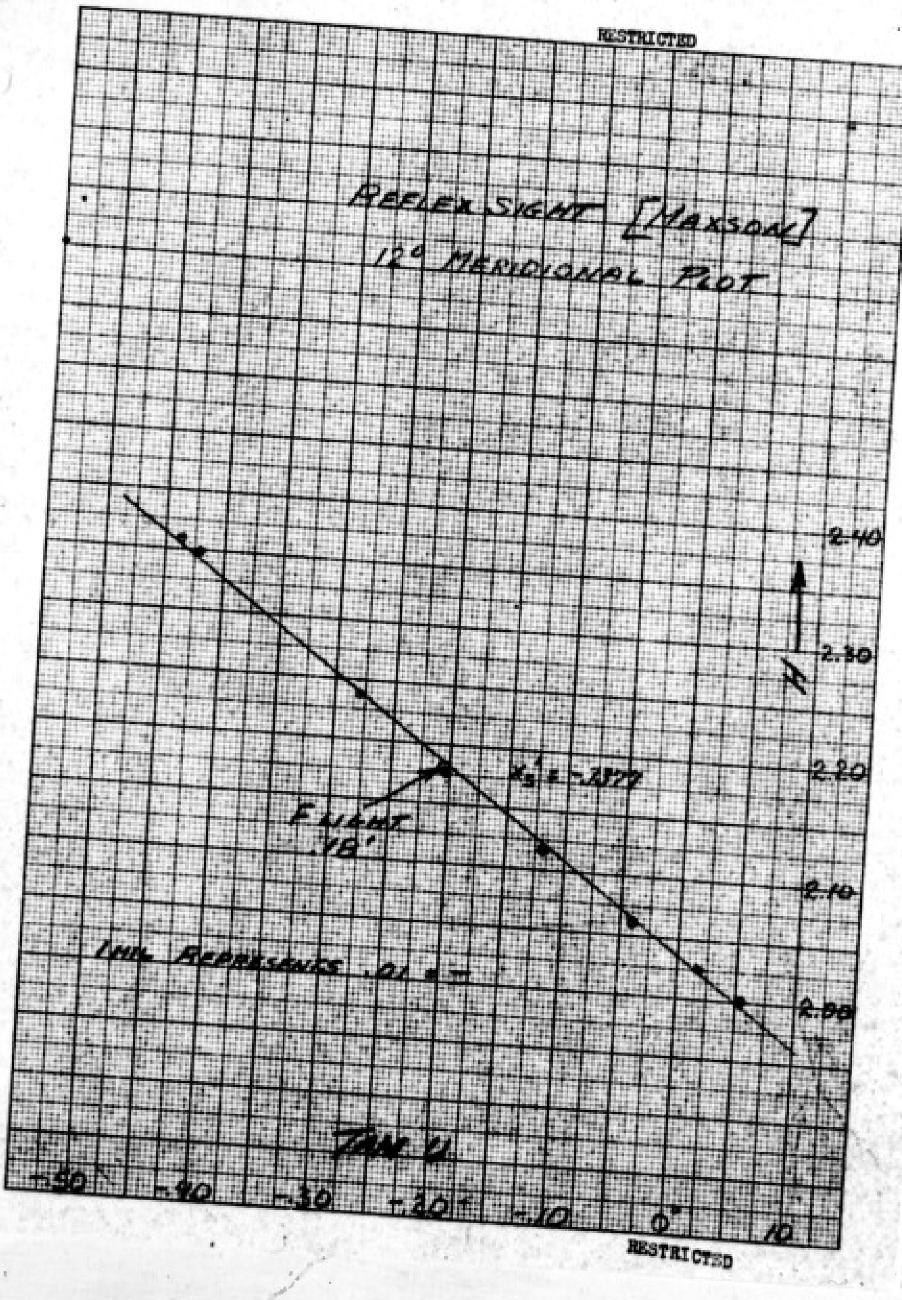

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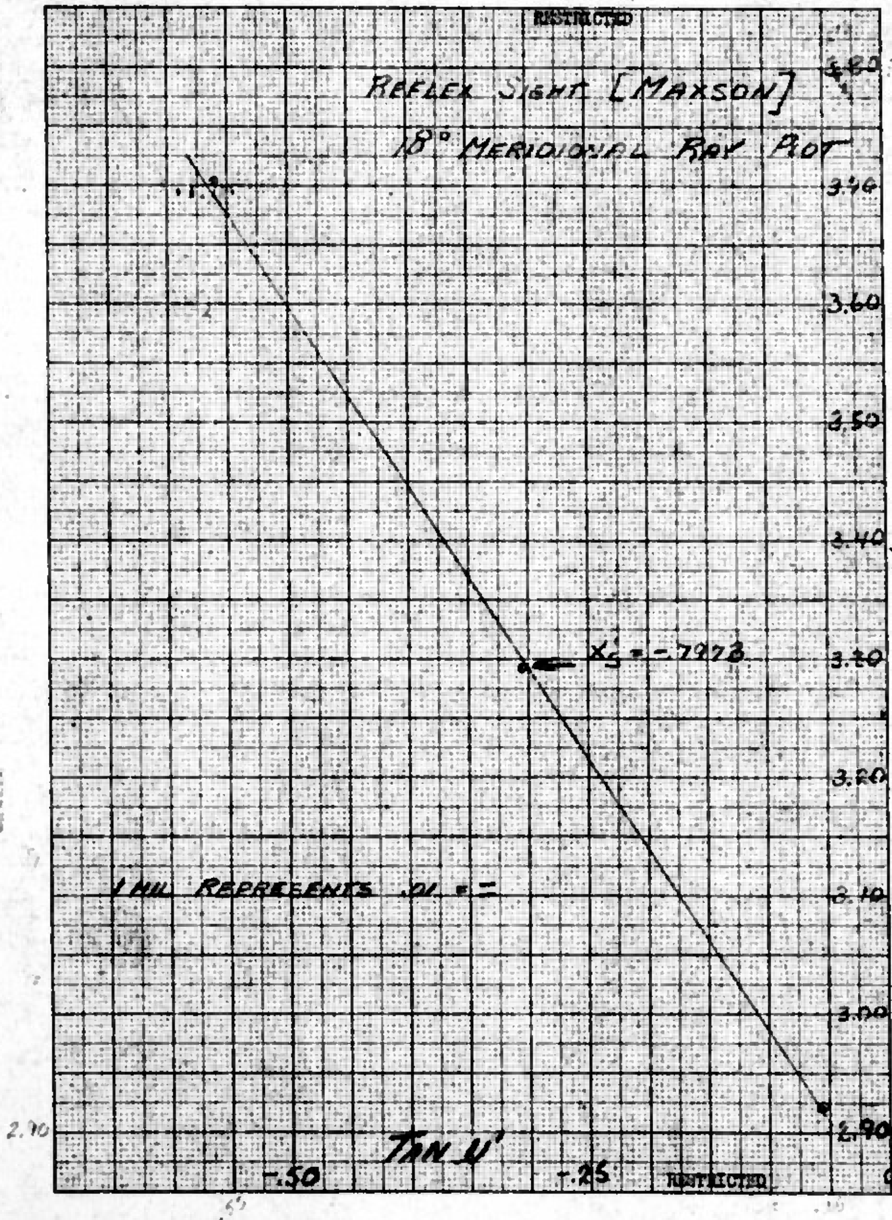

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REFLEX SIGHT [MAXSON]
18° MERIDIONAL RAY PLOT
3.80
3.70
3.60
3.50
3.40
3.30
3.20
3.10
3.00
2.90
H
X'5 = -.7973
1 MIL REPRESENTS .01 = =
TAN U'
-.50
-.25
0
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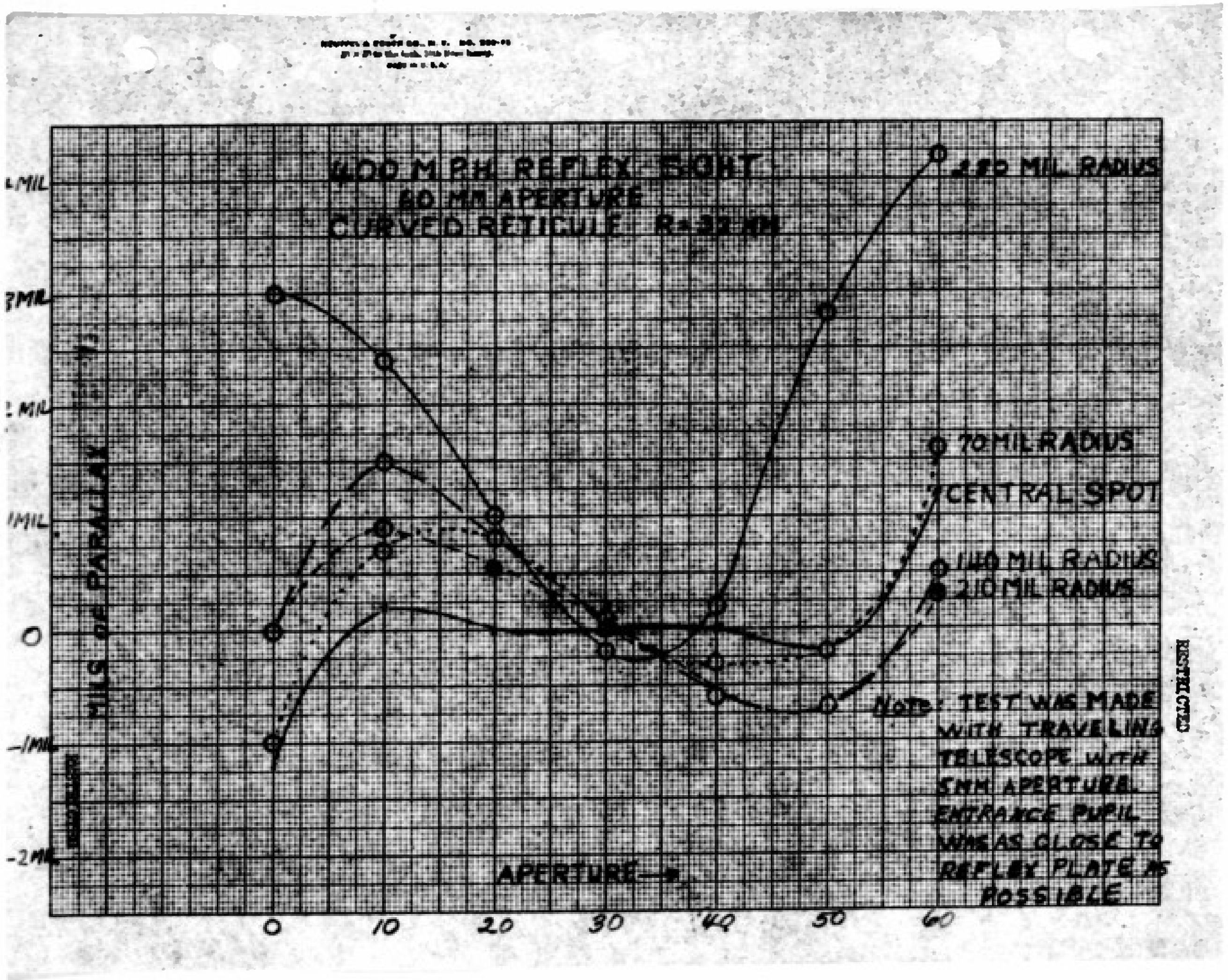
400 M.P.H. REFLEX SIGHT
80 MM APERTURE
CURVED RETICULE R=32 MM
250 MIL RADIUS
70 MIL RADIUS
CENTRAL SPOT
140 MIL RADIUS
210 MIL RADIUS
NOTE: TEST WAS MADE WITH TRAVELING TELESCOPE WITH 5MM APERTURE. ENTRANCE PUPIL WAS AS CLOSE TO REFLEX PLATE AS POSSIBLE
MILS OF PARALLAX
3 MIL
2 MIL
1 MIL
0
-1 MIL
-2 MIL
APERTURE →
0
10
20
30
40
50
60
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REEL – C

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Rochester Univ.

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O.S.R.D. 6032

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FORG'N. TITLE: P2016 Reflex Sights

ORIGINATING AGENCY: O.S.R.D., N.D.R.C., Div. 16, Washington, D. C.

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U.S.	Eng.		Restr.	Sep'45	51	30	photos, tables, drwgs

ABSTRACT

Details of design and performance characteristics of four reflex type gunsights are described. The M-9 airborne sight has a 3-1/2-inch exit pupil aperture and a folded optical path. A radar reflex sight, which was developed, includes illuminated graticule, image of radar cathode ray tube screen, image of gyrohorizon, and an air-speed indicator, all of which are viewed through the sight. Two antiaircraft type sights are also described.

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